Renovation of Center Pivot Systems for Enhanced Irrigation Research

Paul E. Hendrickson, Dean D. Steele, Tom F. Scherer, Aung Hla, and Blaine G. Schatz
North Dakota State University

Abstract

Research on irrigation scheduling and research on multiple crops with differing water needs can become prohibitively expensive unless irrigation infrastructure and land use are optimized. To address these issues, a new two-tower center pivot (CP) was installed and an eight-tower CP was renovated at the Carrington Research Extension Center, Carrington, ND. The two-tower CP (373-ft radius, 200 gpm flow rate, 10 ac area, 20 gpm/acre capacity) allows individual irrigation scheduling for several crops and water management zones. It has pressure regulators on each sprinkler, manual control of individual sprinklers, and computerized control of three sections of sprinklers. Because the system can be programmed to apply water independently to any combination of three zones along its length, the pressure and flow rate can vary considerably, the latter leading us to install a variable-speed motor controller that provides operational flexibility, improves energy efficiency, and reduces high-pressure stresses on the system. The eight-tower CP (958-ft radius, 800 gpm flow rate) was renovated by adding a new sprinkler package with drop nozzles and pressure regulators. A computerized control panel was added, along with control capabilities so irrigations for each of the outer five spans can be independently turned on or off, enabling experiments requiring separate water management zones.

Introduction

The Carrington Research Extension Center began in 1960 as the Carrington Irrigation Station. It was established by the North Dakota Legislature to support the Garrison Diversion Project plan to divert Missouri River water for irrigation. The Carrington research Extension Center introduced center pivot sprinkler irrigation in the state, and evaluated other irrigation systems. To enhance irrigation research, a new two-tower center pivot was installed and an eight-tower center pivot was renovated at the Carrington Research Extension Center, Carrington, ND.

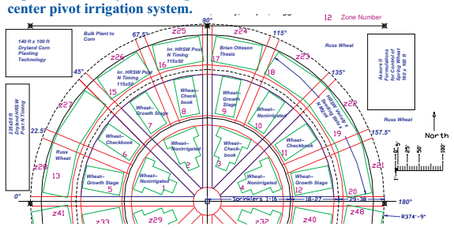
Two-Tower Center Pivot

A new two-tower, high speed, high volume, center pivot irrigation system covering approximately 10 acres was installed in 1999 at the Carrington Research Extension Center (Figure 1). The irrigation system has a 373-ft radius and a capacity of 200 gallons per minute. The capacity of 20 gpm/acre per day is much larger than for typical systems but will allow individual irrigation scheduling for several crops and water management zones. At this rate the pivot can apply about 1 inch of water per day to the entire field. To maintain application accuracy under a variety of conditions, the system has drop nozzles, 20 psi pressure regulators on each sprinkler, and manual control of individual sprinklers. The pivot is controlled by a Reinke Automated Management System (RAMS) computerized main control panel (Figure 2). The pivot sprinkler system is divided into three independently controlled banks and the area under the pivot is divided into 22.5˚ sectors, creating 48 irrigation zones (Figures 1 and 3). With the high speed, high volume design and the computerized control panel, the pivot can be programmed to water any combination of irrigation zones independently of each other on any given day. This affects the power use of the pump because the flow rate and pressure can vary significantly. To solve the problem of varying flow rates and pressures, a variable-speed motor controller was installed to provide operational flexibility. Only one-half of the field is used each year for research purposes. The other one-half of the field is planted to a rotational crop.

Figure 1. Two-tower center pivot irrigation system with zonal control of sprinklers.

Figure 2. Reinke automated management system (RAMS) computerized control panel.

Figure 3. Field layout of irrigation zone under the two-tower center pivot irrigation system.



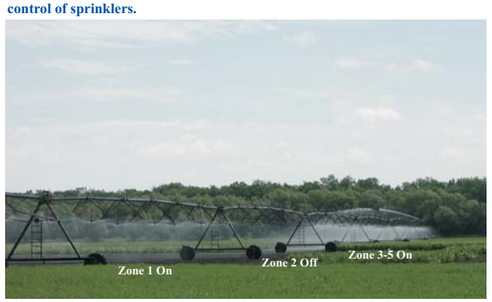
NDSU

Eight-Tower Center Pivot

An existing eight-tower pivot was renovated to enhance irrigation research (Figure 4). The system has a 958-ft radius and a capacity of 800 gpm at 60 psi. A 1-inch application rate requires 48 hours to complete one revolution. A RAMS computerized main control panel was added to control the system (Figure 2). To increase application accuracy, drop nozzles and 40 psi pressure regulators were also added to the system. The pivot sprinkler system is divided into five independently controlled zones (Figure 5) and the area under the pivot is divided into 20 sectors, creating 108 irrigation zones. Since it takes two days to complete a revolution, only about one fourth of the area is used for research. The rest of the area is used to increase foundation seedstock or provide forage for livestock research. The pump for this system is also used to supply water to another eight-tower pivot. When sections of the renovated pivot are turned off, this increases the pressure and strains the system. To alleviate this problem, excess water is diverted to the other eight-tower pivot.

Figure 4. Renovated eight-tower center pivot system.

Figure 5. Renovated eight tower center pivot irrigation system with zonal control of sprinklers.



Variable Speed Controller

The variable-speed motor controller for the two-tower pivot was purchased with a grant from the U.S. Bureau of Reclamation's Water Conservation Field Services Program. This program demonstrates water conservation methods that can be implemented by irrigators. A pressure transducer attached to the pipeline about 15 feet from the pump provided a feedback signal to the controller. The system was tested with a portable power meter and an ultrasonic flow meter. The system was first tested as it is currently run, at full pressure without the controller. The results are shown in Table 1. The system was then tested in the same manner but with the variable-speed motor controller programmed to maintain pipeline pressure at 40 psi. The results are shown in Table 2. The test revealed that the controller maintained a constant pressure while supplying water to a varying number of zones, i.e., across a range of flow rates. Based on these results, there should be a considerable reduction in power costs over the course of a growing season.

Table 1. Flow rates, power use, and pressure at different zones of the two-tower pivot system.

Number of Zones On	Flow Rate	Pump Power Use	Pressure at the Pump
	gpm	kW	psi
3	200	11.8	70
2	146	10.6	90
1	88	9.4	97

Table 2. Flow rates, power use, and motor frequency with the variable speed motor controller programmed to maintain pipeline pressure at 40 psi.

Number of Zones On	Flow Rate	Pump Power Use	Motor Frequency
	gpm	kW	Hz
3	200	8.4	53
2	146	6.2	48
1	88	4.9	44

Installation of the variable-speed motor controller was simple and the operation relatively easy. The menu-driven, step-by-step programming is user friendly. The safety features to protect against low voltage and phase loss are added features. Because the speed of the pump impeller determines the pump pressure, flow rate, and energy consumption, the result of speed decreases was a decrease in energy usage. By keeping the pump pressure constant, operational flexibility is enhanced. In the future, the hand-moved sprinkler and micro-irrigation systems could be run at the same time as the pivot zones with a single pump.

Research Plan

For irrigation water management studies, main plots correspond to irrigation zones (Figure 6). Subplots or splits plots are used in each irrigation zone to study various combinations of fertility, crop variety, or other experimental treatments (Figure 7). For other research projects, different crops are placed in individual irrigation zones and the individual crops can be irrigated according to their specific needs. For example, we will be able to irrigate onions according to a schedule that is independent of the schedule for potatoes (Figure 8). This crop-specific approach to irrigation will allow us to develop better management recommendations than if we irrigated the aggregate of all crops together. In addition, controlling the water appropriately will provide better disease control.

Figure 6.Two-tower center pivot irrigation zones and corresponding main plots for hard red spring wheat and potato water management studies.

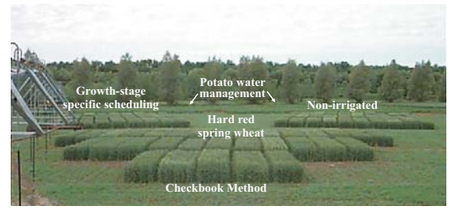


Figure 7. Two-tower center pivot subplots within each irrigation zone used to study various combinations of fertility and variety, or other experimental treatments.

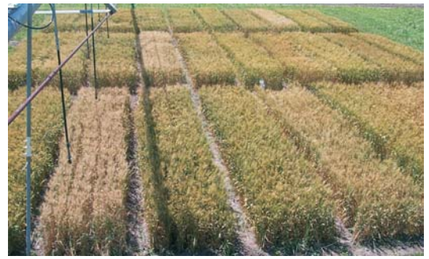


Figure 8. Eight tower center pivot system used for irrigation water management studies and crop specific irrigation.